AP PHYSICS B TEST I

SECTION I—MULTIPLE CHOICE

Time: 90 minutes

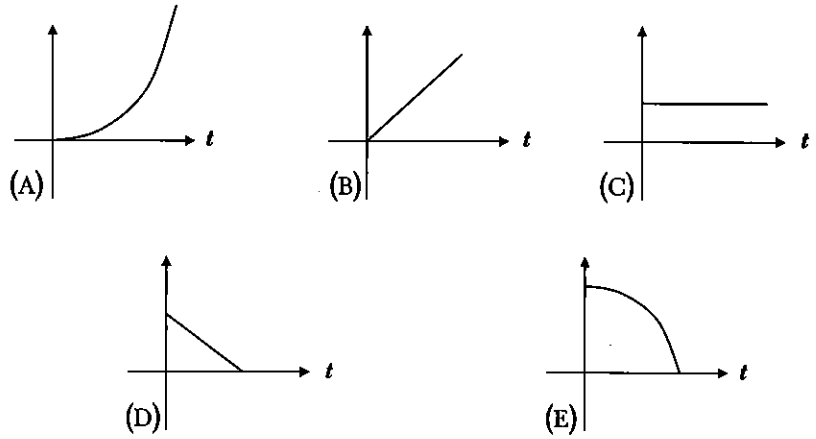
70 Questions

Points: 90

Directions: Each of the questions or incomplete statements below is followed by 5 suggested answers or completions. Select the one that is best in each case.

Note: To simplify calculations, you may use $g = 10\ m/s^2$ in all calculations.

Questions 1 and 2



1. Which graph best represents the displacement of an object accelerating uniformly from rest?

   (A) A (B) B (C) C (D) D (E) E

2. Which graph could represent the momentum of an object after it has been thrown straight up in the air?

   (A) A (B) B (C) C (D) D (E) E

3. A book rests on a flat horizontal table. Which of the following is true?
   I. The reaction force to the weight is the normal force.
   II. The book exerts a force on the Earth equal in magnitude to the weight of the book.
   III. The book exerts a force on the table equal in magnitude to the weight of the book.

   (A) I only (B) II only (C) III only (D) II and III only (E) I, II, and III

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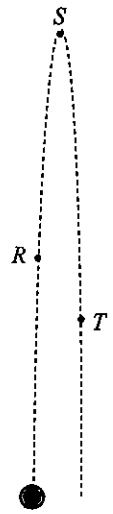
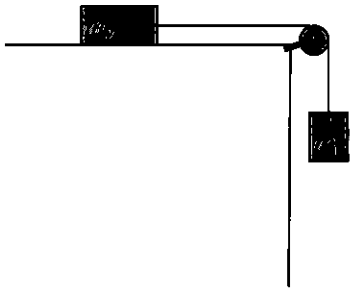


4. An object is projected straight up and passes through the points *R*, *S*, and *T* before returning to the ground, moving under only the influence of gravity. Which of the following best represents the acceleration at each point?

	R	S	T
(A)	↓	0	↓
(B)	↓	0	↑
(C)	↑	0	↓
(D)	↓	↓	↓
(E)	↓	↓	↑



5. Two masses are connected by a light string over an ideal pulley. m_2 slides on a smooth surface. The acceleration of m_2 is

(A) $\frac{m_2}{m_1}g$ (B) $\frac{m_1}{m_2}g$ (C) $\frac{m_1 - m_2}{m_1 + m_2}g$ (D) $\frac{m_2}{m_1 + m_2}g$ (E) $\frac{m_1}{m_1 + m_2}g$

6. A 0.25 kg mass is hung vertically from a spring and allowed to come to rest. If the spring stretches 0.05 m, the value of the spring constant is most nearly

(A) 2.5 N/m (B) 5 N/m (C) 25 N/m (D) 50 N/m (E) 0.5 N/m

7. The following hypothetical situation is described by a physics teacher: Two equal mass objects moving at the same speed collide head-on and rebound with speeds equal to twice their initial speeds. Which of the following is true?

I. Since momentum wasn't conserved, there must have been external forces acting.
II. Energy stored in the masses must have been released.
III. This is an example of an elastic collision.

(A) I only (B) II only (C) III only (D) I and II only (E) I and III only

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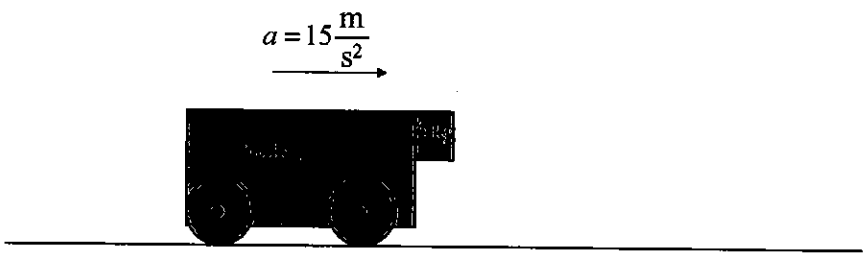
Questions 8 and 9

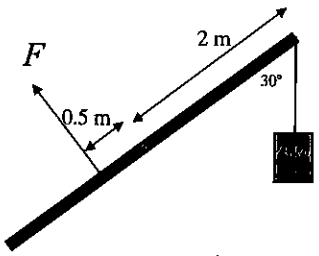


The 4 kg mass doesn't slip as the two masses accelerate at 15 m/s^2.

8. The force exerted by the 10 kg mass on the 4 kg mass is best represented by

(A) ↑ (B) ↗ (C) → (D) ↖ (E) ←

9. From the information given, what can be determined about the coefficient of static friction between the two masses?
(A) No information can be determined because the system is moving.
(B) The coefficient of static friction is less than the coefficient of kinetic friction.
(C) $\mu = \frac{2}{3}$ (D) $\mu \leq \frac{2}{3}$ (E) $\mu \geq \frac{2}{3}$



10. A uniform plank 4 m long is pivoted about its center to an angle of 30° with the vertical. What magnitude of force must be applied 0.5 m from the pivot to maintain equilibrium with a 4 kg mass hanging from one end?
(A) 80 N (B) 20 N (C) 40 N (D) 60 N (E) 100 N

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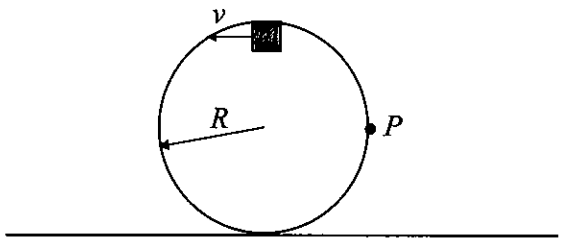
11. A 4 kg mass initially moving at 10 m/s at the bottom of a 37° incline barely makes it to the top before coming to rest. The work done by friction is most nearly

(A) 200 J (B) −200 J (C) −120 J (D) 80 J (E) −80 J

12. A 60 kg student runs up the stairs from the basement to the third floor in 10 s. If the height change between floors is 4 m, the average power output of the student was closest to

(A) 1,000 W (B) 10,000 W (C) 700 W (D) 7,000 W (E) 70 W

Questions 13 and 14



13. A toy car is at the top of a loop-the-loop moving with speed v such that the track exerts a non-zero force on the car. The force exerted on the car by the track at this point has a value

(A) $\frac{mv^2}{R}$ (B) $\frac{mv^2}{R} - mg$ (C) $mg - \frac{mv^2}{R}$ (D) $\frac{mv^2}{R} + mg$ (E) mg

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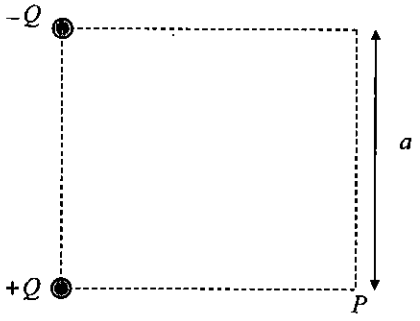
14. Which of the following is true at P, located halfway up the loop?
    I. The force of gravity and the normal force are equal in magnitude.
    II. The centripetal force is supplied by the normal force only.
    III. The centripetal force is equal to the difference in the normal force and the force of gravity.

    (A) I only (B) II only (C) III only (D) I and II only (E) I and III only

15. A neutral conducting sphere hangs vertically by an insulating thread. A nonconducting sphere of the same radius and carrying a charge $+Q$ is placed close to the first sphere. Which of the following is true?
    I. The neutral sphere will experience 0 force.
    II. The neutral sphere will be attracted to the charged sphere.
    III. Charges on the neutral sphere will reposition in response to the charged sphere.

    (A) I only (B) II only (C) III only (D) I and III only (E) II and III only

Questions 16 and 17



Two charges are fixed at the corners of a square of side a as shown in the figure.

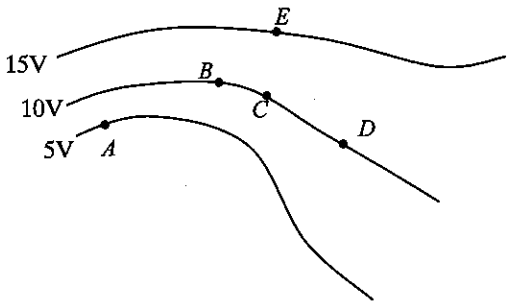
16. The direction of the electric field at point P is best represented by

    (A) ↑ (B) ↗ (C) ↘ (D) ↖ (E) ↙

17. The potential energy of a charge q placed at the center of the square is

    (A) $k\frac{qQ}{\sqrt{2}a}$ (B) $k\frac{2qQ}{\sqrt{2}a}$ (C) $k\frac{4qQ}{\sqrt{2}a}$ (D) 0 (E) $k\frac{qQ}{2\sqrt{2}a}$

Questions 18–20



The figure shows several equipotential surfaces.

18. At which point is the electric field strongest?

(A) A (B) B (C) C (D) D (E) E

19. The work it would take to move $a + 2$ C from C to D is closest to

(A) + 20 J (B) − 20 J (C) 0 (D) + 10 J (E) − 10 J

20. An electron released from rest at point C would most likely pass through which point a short time later?

(A) A (B) B (C) C (remain here) (D) D (E) E

21. 10^8 electrons move through a section of wire every 10 s. The electric current in the wire is closest to

(A) 10^8 A (B) 10^7 A (C) 10^{-11} A (D) 10^{-12} A (E) 10^{-8} A

22. At a depth of 5 m in a static fluid open to the atmosphere, the pressure is determined to be 3×10^4 Pa above atmospheric pressure. The density of the fluid is closest to

(A) 600 $\frac{\text{kg}}{\text{m}^3}$ (B) 300 $\frac{\text{kg}}{\text{m}^3}$ (C) 6,000 $\frac{\text{kg}}{\text{m}^3}$ (D) 1,000 $\frac{\text{kg}}{\text{m}^3}$ (E) 3,000 $\frac{\text{kg}}{\text{m}^3}$

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23. A rectangular solid of cross-sectional area A and thickness t floats in a fluid of density ρ_f such that only a portion h of the thickness is below the surface of the fluid. The density of the solid is

(A) $\frac{t-h}{h}\rho_f$ (B) $\frac{t-h}{t}\rho_f$ (C) $\frac{t}{h}\rho_f$ (D) $\frac{h}{t}\rho_f$ (E) $\frac{th}{A}\rho_f$

24. When a mass with density ρ is hung vertically from a spring with spring constant k, it is found to stretch the spring a distance x_1. With the spring attached, the mass is then lowered into a fluid with density $\rho_f < \rho$, and the spring stretch is now x_2. The volume of the fluid displaced by the mass is

(A) $\frac{k(x_2 - x_1)}{\rho g}$ (B) $\frac{k(x_2 - x_1)}{\rho_f g}$ (C) $k(x_2 - x_1)\rho g$ (D) $k(x_2 - x_1)\rho_f g$ (E) $\frac{kx_2}{\rho_f g}$

25. A liquid is enclosed in a cylindrical container with a piston that can move vertically, and it's currently adjusted to barely touch the top of the fluid. As the piston is forced further into the fluid, which of the following is true?

(A) The pressure in the fluid remains the same.
(B) The pressure increase in the fluid is the same at all points in the fluid.
(C) The pressure increase in the fluid is greatest near the piston.
(D) The pressure increase in the fluid is greatest near the bottom of the container.
(E) The pressure increase in the fluid is greatest at the sides of the container.

26. A gas is rapidly compressed adiabatically. Which of the following is true?

(A) The internal energy decreased, and the pressure increased.
(B) The temperature increased, and the pressure decreased.
(C) Heat energy flowed into the system.
(D) Heat energy flowed out of the system.
(E) The internal energy increased, and the temperature increased.

27. An object is observed to float when placed in a fluid. Which of the following is true?
I. The density of the fluid is greater than the density of the object.
II. As it floats, the object will displace an amount of water having a mass equal to the mass of the object.
III. When completely submerged, the object will displace an amount of water having a volume equal to the volume of the object.

(A) I only (B) I and II only (C) I and III only (D) II and III only (E) I, II, and III

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28. Which of the following can be easily used to relate the energy content at different points in a fluid?

(A) Bernoulli's principle (B) Pascal's principle (C) Archimedes' principle
(D) uncertainty principle (E) Fermat's principle

29. Which of the following processes involves a heat transfer to a cool metal rod?
I. Place the rod in direct sunlight.
II. Hammering the rod.
III. Place the rod in a hot water bath.

(A) I and III only (B) I and II only (C) I, II, and III (D) III only (E) II and III only

30. The conduction electrons in a metal are sometimes approximated as behaving as an ideal gas. This isn't a good approximation because

(A) the temperature of the metal isn't hot enough to support a gas
(B) the electrons are too big
(C) there isn't enough space in the metal for a gas to move
(D) the electrons will exert long-range forces on each other
(E) electrons cannot have elastic collisions with each other

31. For an isothermal process involving an ideal gas, which of the following is true?

(A) The pressure must increase.
(B) The internal energy remains the same.
(C) The volume must decrease.
(D) The volume must increase.
(E) The entropy remains the same.

32. An object is placed inside the focal length of a converging mirror. Which of the following is true?

(A) A real image smaller than the object is formed in front of the mirror.
(B) A virtual image smaller than the object is formed behind the mirror.
(C) A real image larger than the object is formed in front of the mirror.
(D) A virtual image larger than the object is formed behind the mirror.
(E) A virtual image equal in size to the object is formed behind the mirror.

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33. An object is placed outside the focal length of a diverging mirror. Which of the following is true?

(A) A real image smaller than the object is formed in front of the mirror.
(B) A virtual image smaller than the object is formed behind the mirror.
(C) A real image larger than the object is formed in front of the mirror.
(D) A virtual image larger than the object is formed behind the mirror.
(E) A virtual image equal in size to the object is formed behind the mirror.

34. An object is placed at a distance $2f$ from a converging lens, where f is the focal length. The object is moved slowly inward to a distance $\frac{3}{2}f$. Which of the following is true for the image?

(A) The image changed from a real image to a virtual image.
(B) The image changed from an upright image to an inverted image.
(C) The image remained real but got smaller.
(D) The image remained real but got larger.
(E) The image remained virtual but got smaller.

35. An object is placed at a distance $\frac{1}{2}f$ from a diverging lens where f is the focal length. The object is moved slowly outward to a distance $2f$. Which of the following is true for the image?

(A) The image changed from a virtual image to a real image.
(B) The image changed from an upright image to an inverted image.
(C) The image remained virtual but got smaller.
(D) The image remained virtual but got larger.
(E) The image remained real but got larger.

36. In a photoelectric experiment, it's found that a certain wavelength of light will not cause any electrons to be ejected. To begin to cause electrons to be ejected, what must be done?

(A) Increase the wavelength of the light.
(B) Increase the intensity of the light.
(C) Increase the potential of the collector.
(D) Decrease the frequency of the light.
(E) Decrease the wavelength of the light.

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37. A focused beam of electrons is passed through a single slit that's very large compared with the De Broglie wavelength of the electron. When a screen is placed behind the slit, which of the following is true?

(A) The electrons will strike points on the screen directly behind the slit.
(B) The electrons will exhibit a wavelength shift.
(C) A distinct pattern of maxima and minima will appear on the screen.
(D) The electrons will scatter off Huygens emitters within the slit.
(E) A diffraction pattern will appear if the electron energies are above threshold.

38. In a nuclear reaction, a boron nucleus ${}^{10}_{5}B$ collides with another particle, producing one lithium nucleus ${}^{7}_{3}Li$ and a helium nucleus ${}^{4}_{2}He$. The other particle is a

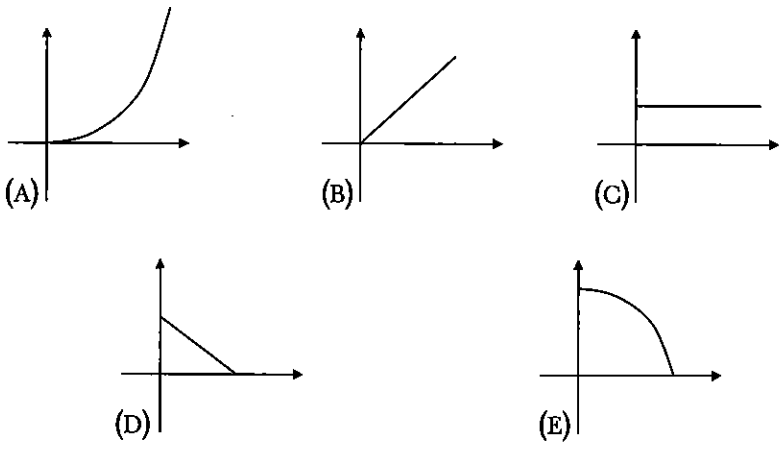
(A) neutron (B) proton (C) photon (D) electron (E) ${}^{4}_{2}He$

39. How many neutrons are produced in the following nuclear reaction?

${}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr +$?neutrons

(A) 0 (B) 1 (C) 2 (D) 3 (E) 4

40. A mass is dropped from rest off the edge of a building. The graph that best depicts the power delivered to the mass as a function of time is



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41. Falling freely from rest for 1 s, a 2 kg mass collides in midair with a 3 kg mass that is instantaneously at rest. If the two masses stick together, their speed just after the collision is most nearly

(A) 10 m/s (B) 0.2 m/s (C) 5 m/s (D) 4 m/s (E) 1 m/s

42. A 4 kg mass moving in one dimension with a velocity of +10 m/s is decelerated in 2 s to a speed of +3 m/s by a constant force. The value of the force is

(A) −14 N (B) −26 N (C) −28 N (D) 14 N (E) 26 N

43. A 4 kg mass moving east at 10 m/s collides with a 1 kg mass moving north at 40 m/s. The two masses stick together. Just after the collision, the speed of the combined object is

(A) $8\ \frac{m}{s}$ (B) $8\sqrt{2}\ \frac{m}{s}$ (C) $16\ \frac{m}{s}$ (D) $50\ \frac{m}{s}$ (E) $30\ \frac{m}{s}$

44. A 2 kg mass and a 6 kg mass are at rest on a smooth horizontal surface. With a light spring placed between them, the two masses are pushed together, compressing the spring. Then they're released, allowing the masses to fly apart and leaving the spring behind. Which of the following is true?

(A) The 6 kg mass exerts a larger force on the spring than the 2 kg mass.
(B) The two masses separate with equal speeds.
(C) Energy and momentum are conserved. The 2 kg mass moves off at 4 times the speed of the 6 kg mass.
(D) Energy is not conserved, but momentum is conserved. The 2 kg mass moves off at 3 times the speed of the 6 kg mass.
(E) When the 2 kg mass has traveled 12 m, the 6 kg mass has traveled 4 m.

45. A 2 kg mass is moving in an *x*-*y* plane. At one instant it is at the point (3, 4) moving in the negative *y*-direction with a speed of 7 m/s. The magnitude of its angular momentum about the origin is

(A) $14\ \frac{kg \cdot m^2}{s}$ (B) $56\ \frac{kg \cdot m^2}{s}$ (C) $70\ \frac{kg \cdot m^2}{s}$ (D) $42\ \frac{kg \cdot m^2}{s}$ (E) 0

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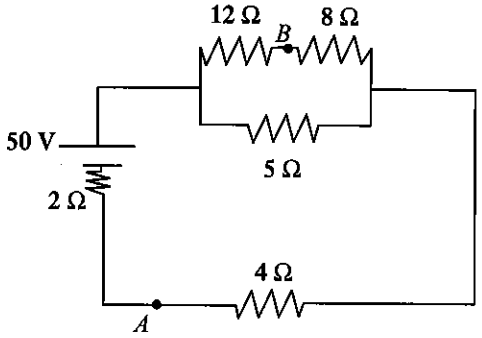
46. Two 4 Ω and one 100 Ω resistors are connected in parallel. Their equivalent resistance is closest to

(A) 2 Ω (B) 4 Ω (C) 108 Ω (D) 1 Ω (E) 0.5 Ω

Questions 47–49



A 50 V battery with internal resistance 2 Ω is connected to several resistors as shown.

47. The terminal voltage of the battery is

(A) 48 V (B) 40 V (C) 50 V (D) 52 V (E) 60 V

48. The power consumed by the 5 Ω resistor is

(A) 80 W (B) 5 W (C) 50 W (D) 125 W (E) 200 W

49. An ideal voltmeter connected between *A* and *B* would read

(A) 50 V (B) 8 V (C) 40 V (D) 20 V (E) 28 V

50. Fluid is flowing horizontally in a pipe system. At one point where the pipe radius is 0.04 m, the flow speed is 3 m/s. If the pipe narrows to 0.01 m, the flow speed will be

(A) 9 m/s (B) 6 m/s (C) 27 m/s (D) 48 m/s (E) 12 m/s

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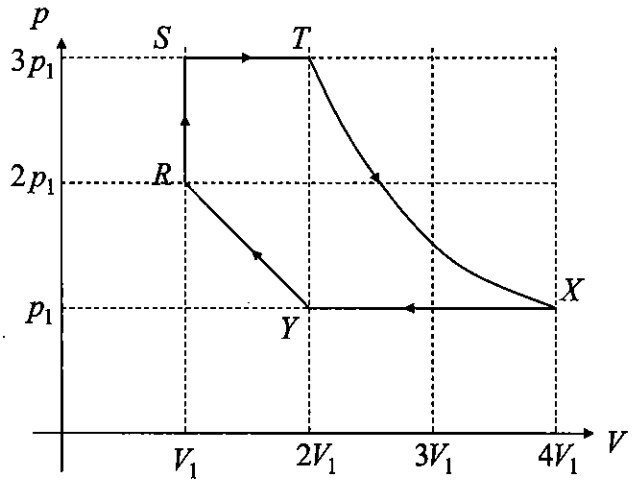
51. A cylindrical container with a moveable piston at one end is completely filled with water and held horizontal. A force is applied to the piston, and when the fluid pressure in the container reaches 3×10^5 Pa, a small hole develops at the other end of the cylinder. At the instant the hole develops, the speed of the water emerging from the cylinder is closest to which one of the following? (Assume atmospheric pressure is 1×10^5 Pa, and the density of water is $1{,}000 \frac{\text{kg}}{\text{m}^3}$.)

(A) 10 m/s (B) 20 m/s (C) 30 m/s (D) 40 m/s (E) 50 m/s

Questions 52–54



One mole of ideal gas is the working substance for a heat engine with a pV diagram shown in the figure.

52. The change in internal energy in the process RS is

(A) 0 (B) $\frac{1}{2}p_1V_1$ (C) $\frac{3}{2}p_1V_1$ (D) $3p_1V_1$ (E) $\frac{5}{2}p_1V_1$

53. The work done by the gas during the process ST is

(A) 0 (B) p_1V_1 (C) $2p_1V_1$ (D) $3p_1V_1$ (E) $6p_1V_1$

54. The total work done over the entire cycle is closest to

(A) 0 (B) p_1V_1 (C) $2p_1V_1$ (D) $3p_1V_1$ (E) $4p_1V_1$

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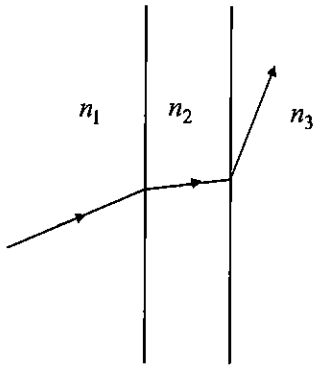
55. A ray of light with wave speed v and wavelength λ is incident on a surface where the index of refraction is less than in the incident medium. Which of the following is true for the refracted beam having wave speed v' and wavelength λ'?

(A) The ray bends toward the normal, $\lambda' < \lambda$, $v' < v$.
(B) The ray bends away from the normal, $\lambda' < \lambda$, $v' < v$.
(C) The ray bends toward the normal, $\lambda' > \lambda$, $v' > v$.
(D) The ray bends away from the normal, $\lambda' > \lambda$, $v' > v$.
(E) The ray bends away from the normal, $\lambda' > \lambda$, $v' < v$.



56. A light ray moves across two interfaces as shown in the figure. Which of the following relations is true for the three indices of refraction?

(A) $n_1 > n_2$, $n_2 > n_3$, $n_1 > n_3$
(B) $n_1 < n_2$, $n_2 > n_3$, $n_1 < n_3$
(C) $n_1 > n_2$, $n_2 > n_3$, $n_1 < n_3$
(D) $n_1 < n_2$, $n_2 > n_3$, $n_1 > n_3$
(E) $n_1 < n_2$, $n_2 < n_3$, $n_1 < n_3$

57. A prism with index of refraction $\frac{3}{2}$ is illuminated with white light and the emerging rays exhibit dispersion, with the red separated from the violet by an angle of 2°. The prism is now placed under water having index of refraction $\frac{4}{3}$ and illuminated in exactly the same way. Which of the following is true?

(A) There is no dispersion in this case.
(B) The order of the colors is the same, but the angular separation is greater.
(C) The order of the colors is the same, but the angular separation is smaller.
(D) The order of the colors is reversed, and the angular separation is greater.
(E) The order of the colors is reversed, and the angular separation is smaller.

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58. At a height of 1 km above the Earth, an object has a weight of 100 N. If this object is then brought to a height of 10 km above the Earth, its weight would be closest to

(A) 10 N (B) 1 N (C) 100 N (D) 0.1 N (E) 50 N

Questions 59 and 60

A 2 kg mass moving at 4 m/s over a smooth horizontal surface collides with an identical mass attached to a spring with spring constant 64 N/m. The two masses stick together.

59. The period of the resulting oscillations is closest to

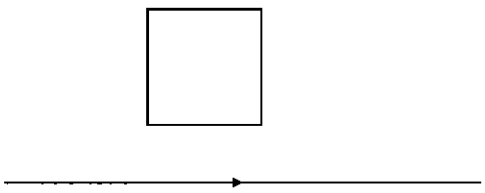
(A) 1 s (B) 1.5 s (C) 2 s (D) 2.5 s (E) 3 s

60. The amplitude of the resulting oscillations is closest to

(A) $\frac{\sqrt{2}}{2}$ m (B) $\frac{1}{2}$ m (C) $\sqrt{2}$ m (D) 2 m (E) $\frac{2}{\sqrt{2}}$ m

61. An electron moves in a region of uniform magnetic field with a velocity that currently makes an angle of 45° with the field. Which of the following is true?

(A) The electron will move in a circle at constant speed.
(B) The electron will move in a circle, gradually increasing in speed.
(C) The electron will move in a helix at constant speed.
(D) The electron will move in a helix, gradually increasing in speed.
(E) The electron will move in a straight line at constant speed.



62. A square loop is placed near a long current-carrying wire that's carrying current to the right in the figure. The current is decreased to 0 over a time t. Which of the following is true while the current is changing?

I. The loop will experience a net force toward the long wire.
II. A clockwise current is induced in the loop.
III. An electric field is created around the long wire.

(A) I only (B) I and II only (C) I and III only (D) II and III only (E) III only

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63. A fluid with density ρ and speed v flows through a horizontal pipe system. If the radius of the pipe increases by a factor of 2, the change in pressure is closest to which of the following?

(A) $\frac{1}{2}\rho v^2$ (B) ρv^2 (C) $\frac{3}{2}\rho v^2$ (D) $2\rho v^2$ (E) $\frac{5}{2}\rho v^2$

64. When the temperature of an ideal gas is doubled,

(A) the volume must increase
(B) the pressure must increase
(C) the molecular speeds double
(D) the molecular speeds increase by a factor of 4
(E) the molecular speeds increase by a factor of $\sqrt{2}$

65. A Carnot engine operates between hot and cold reservoirs of temperatures 600 K and 200 K, respectively. Every hour, 100 MJ is expelled from the engine to the cold reservoir. The useful work performed by the engine every hour is

(A) 100 MJ (B) 150 MJ (C) 200 MJ (D) 250 MJ (E) 300 MJ

66. A mass moves in an elliptical orbit about the Sun. Which property of the mass remains the same as it executes its orbit?

(A) kinetic energy (B) angular momentum (C) acceleration
(D) potential energy (E) linear momentum

67. An acceptable unit for torque is

(A) $\frac{\text{kg} \cdot \text{m}}{\text{s}}$ (B) $\text{N} \cdot \text{s}$ (C) $\frac{\text{J}}{\text{s}}$ (D) $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$ (E) $\text{N} \cdot \text{J}$

68. A mass m slides across a smooth horizontal table, moving at speed v. It collides head on with an identical stationary mass attached to a spring with spring constant k. The two masses stick together after the collision. The time it takes for the spring to reach its maximum compression is most nearly

(A) $\frac{\pi}{2}\sqrt{\frac{m}{k}}$ (B) $2\pi\sqrt{\frac{m}{k}}$ (C) $\frac{\pi}{2}\sqrt{\frac{2m}{k}}$ (D) $2\pi\sqrt{\frac{2m}{k}}$ (E) $\frac{\pi}{2}\sqrt{\frac{k}{m}}$

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69. In a nuclear fusion reaction, 2 ${}_2^3\text{He}$ nuclei combine to form another nucleus, and 2 energetic protons are also produced. The other nucleus is

(A) ${}_1^1\text{H}$ (B) ${}_1^2\text{H}$ (C) ${}_2^2\text{He}$ (D) ${}_2^4\text{He}$ (E) ${}_3^4\text{Li}$

70. If the masses of the neutron and proton are m_n and m_p, respectively, which of the following is true for the mass of the helium nucleus ${}_2^3\text{He}$?

(A) $m_{He} = 2m_p - m_n$ (B) $m_{He} = 2m_p + m_n$ (C) $m_{He} = 2m_n + m_p$
(D) $m_{He} < 2m_p + m_n$ (E) $m_{He} > 2m_p + m_n$

STOP
END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

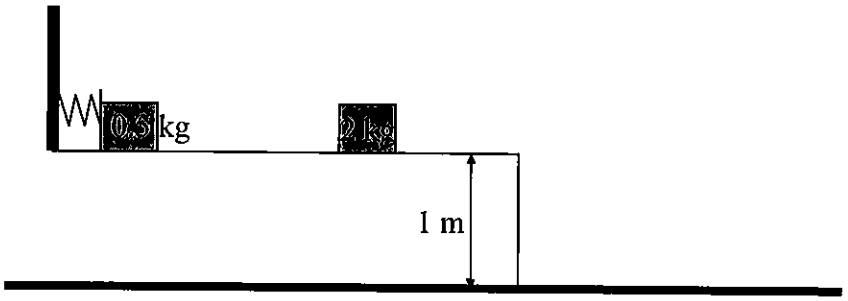
AP PHYSICS B TEST I

SECTION II—FREE RESPONSE

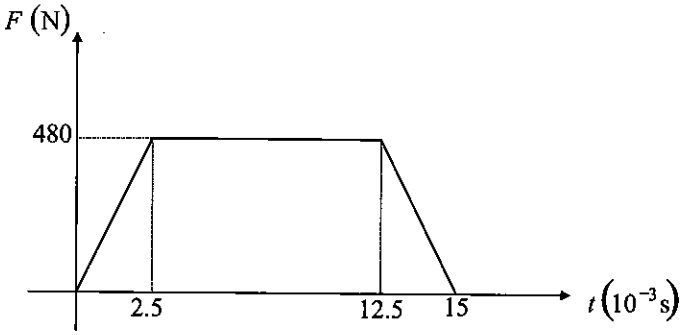
Time: 90 minutes

7 Questions

Directions: Answer all 7 questions, which are weighted according to the points indicated. The suggested time is about 15 minutes for answering each of questions 1–4, and about 10 minutes for answering each of questions 5–7. The parts within a question may not have equal weight.



1. (15 points)
A 0.5 kg mass, resting on a smooth tabletop 1 m high, is pushed into a spring with spring constant 200 N/m as shown in the figure. With the spring compressed 0.5 m, the mass is released, and after it loses contact with the spring it collides with a stationary 2 kg mass. A graph of the force exerted on the 2 kg mass during the collision is shown below.



(a) Determine the speed of the 0.5 kg mass after it has left the spring, but before it has hit the 2 kg mass.
(b) Determine the speed of the 2 kg mass after the collision.
(c) Determine the energy lost in the collision.
(d) Determine the distance between the impact points of each object when they finally strike the ground.

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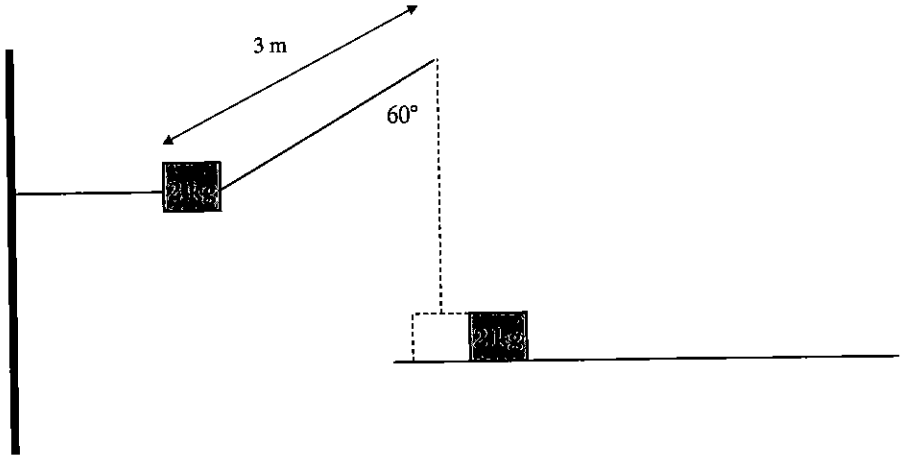

2. (15 points)
A 2 kg mass is suspended by two ropes, one horizontal and one—3 m in length—at an angle of 60° with the vertical, as shown in the figure.
(a) Find the tension in each rope.

The horizontal rope is cut, and the mass swings down and collides with an identical mass resting on a smooth horizontal surface. At the instant the two masses collide, the rope breaks.

(b) Find the speed of the swinging mass just before the collision.
(c) Find the tension in the rope just before it breaks.

The two masses stick together after the collision.
(d) Find the speed of the masses after the collision, assuming they stick together.
(e) Is kinetic energy conserved as a result of the collision? Justify your answer.

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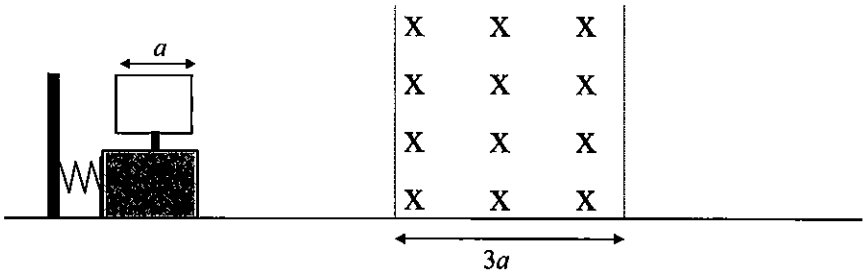
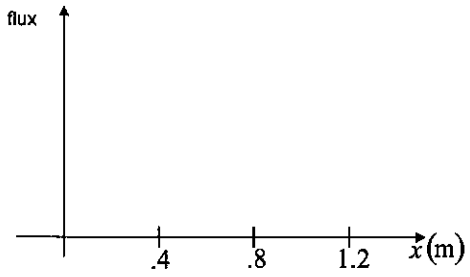
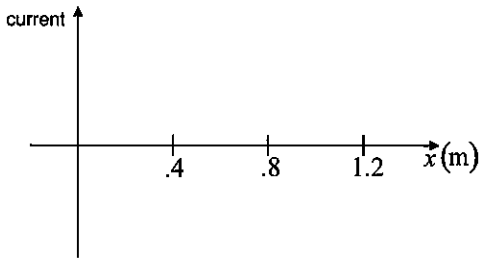


3. (15 points)
A square wire loop of side $a = 0.4$ m and resistance 2 Ω is secured to the top of a block so that their total mass is 0.25 kg. The block is pushed 0.3 m into a spring with $k = 100$ N/m and released, causing the block to slide across a smooth horizontal table. Eventually, the block enters a region of constant magnetic field with strength 0.2 T directed into the page. The width of the field region is 3 times the width of the loop.

(a) Determine the speed of the loop just before it enters the field region.
(b) What is the value of the induced voltage in the loop when the loop first enters the field region?
(c) On the axes below, sketch the magnetic flux through the loop as a function of position. Begin when the front edge of the loop is about to enter the field region and end after the loop has just left the field region.



(d) On the axes below, sketch the induced current as a function of position. Follow the convention that counterclockwise currents are positive.



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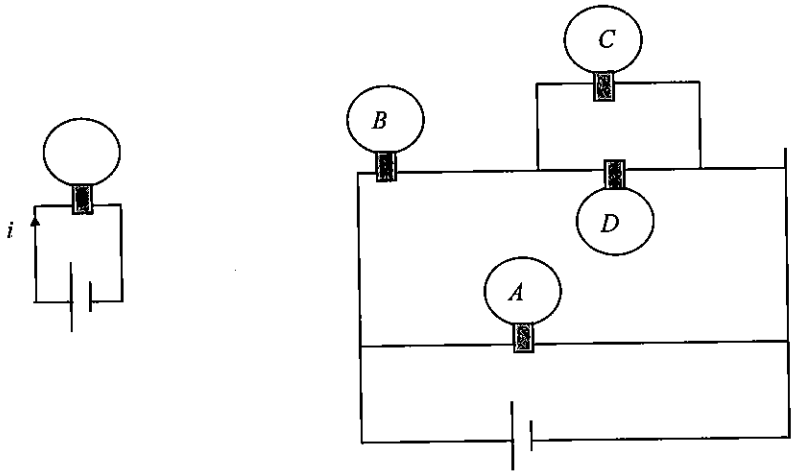

4. (15 points)
When a single light bulb of resistance R is connected to a battery as in the figure, a current i flows in the bulb. An identical battery is connected to a circuit consisting of four bulbs identical to the single bulb. Assume the bulbs behave as ideal resistors.
   (a) How much energy is supplied to the single bulb by the battery in a time t?
   (b) In terms of i, determine the current in each bulb in the larger circuit.
   (c) Describe the brightness of each bulb in the larger circuit, expressing it as a fraction of the brightness of the single bulb in the smaller circuit.
   (d) In each of the following cases, one bulb of the larger circuit fails. Describe the brightness of the remaining bulbs as in part c.
      (i) Bulb A fails.
      (ii) Bulb C fails.

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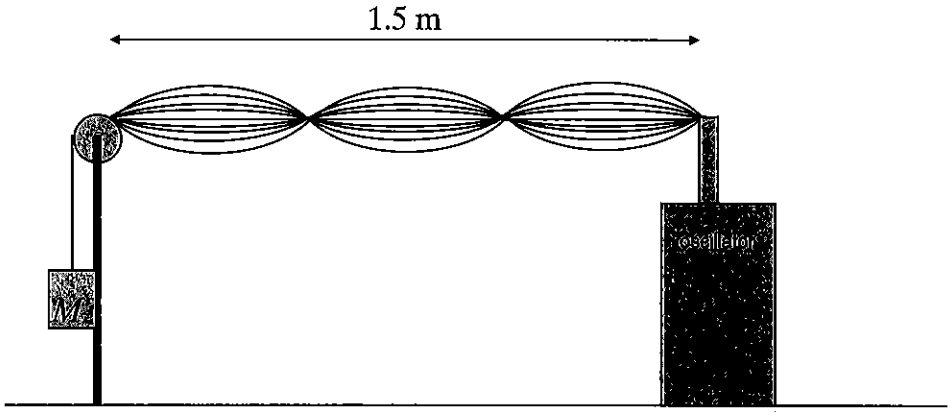
5. (10 points)
In a photoelectric experiment, 480 nm light incident upon a metal surface requires a stopping potential of 1.85 eV.
(a) What is the work function of the material?
(b) Determine the threshold wavelength for the experiment.
(c) What wavelength of incident radiation would be needed so that a stopping potential of 3 V is required?
(d) What is the De Broglie wavelength of the ejected electrons in part c?
(e) Describe an experiment that could be performed with the electrons in part c that would demonstrate their wave properties.



6. (10 points)
A string of length 1.5 m is connected at one end to a mechanical oscillator with a variable frequency. The other end runs over a pulley to a mass M that hangs vertically. When the oscillator frequency is set to 100 Hz, the standing wave in the figure is set up on the string.
(a) What is the wavelength of the standing wave?
(b) What is the wave speed on the string?
(c) What is the lowest frequency of the oscillator that will produce a standing wave?
(d) With the oscillator fixed at 100 Hz, the mass M is slowly increased. Describe qualitatively the features of the standing wave as the mass is increased.

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7. (10 points)
You have been given a pen laser of unknown wavelength and a diffraction grating that is 2.5×10^{-3} m wide, containing 80 equally spaced slits. You have also been given another diffraction grating of unknown slit spacing. Using only passive, nonelectronic equipment, you are to devise a method for measuring the wavelength of the laser and determining the spacing of the unknown grating.
(a) List the equipment you will need.
(b) Draw a diagram showing how the apparatus is set up.
(c) Describe what your apparatus does.
(d) Show how your measurements will give the desired wavelength and spacing.

END OF EXAM

STOP